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Used plastic materials as mulches: An alternative to conventional black plastic mulch for small and marginal farmers

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ABSTRACT

The return of ladies finger (okra) to the joint effect of drip irrigation and mulches is very encouraging. The most common types of mulch are the black plastic mulch (BPM), which is commercially produced by industry but does create environmental problems and increased cost of production particularly for small and marginal farmers. On the other hand, food materials and fertilizers etc. are available and sold in plastic bags. Can we make REUSE of these plastic bags in preparing low cost mulching system for small and marginal farmers? With this in view a field experiment was carried out during the year 2017 at Department of Soil and Water Engineering, Swami Vivekanand College of Agricultural Engineering and Technology & Research Station, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India. The research experiment was performed in a split plot design on clay loam soil during summer season (February to May) for growing okra. Levels of irrigation were assigned based on crop evapotranspiration (ET_c). The effect of four irrigation levels viz. 60% ET_c, 80% ET_c, 100% ET_c and 120% ET_c with drip under black plastic mulch (BPM) and different types used plastic material as mulch viz. used reddish rice bag mulch (RBM), used whitish wheat flour bag mulch (WFBM), used white fertilizer bag mulch (FBM) were studied for moderating the temperature, moisture conservation, weed restriction, yield, water use efficiency and cost economics also. Temperature measurement was done with Digital Soil Thermometer at a depth of 7.6 cm and 12 cm at 7:30 a.m. and 2:30 p.m. It reflects that used plastic mulches are moderating the temperature at par as BPM. Soil moisture measurement was done with Time Domain Reflectometry (TDR) at 7.6 and 12 cm. Average moisture content under BPM, WFBM, RBM and FBM at 7.6 cm was found to be 27.5%, 25.5%, 26.5% and 26.4% respectively, while it was found to be 23.8%, 21.8%, 22.7% and 22.4% respectively at 12 cm depth. Maximum weed population control (96%) was recorded with BPM followed by used RBM (82%), used FBM (80%) and used WFBM (76%) respectively. The benefit cost ratio was also worked out and found to be higher (2.09) under 120% ET_c with BPM as compared to 120% ET_c with used RBM (1.86), 120% ET_c with used WFBM (1.82) and 80% ET_c with used WFBM (1.81). Highest Crop Water Use Efficiency (42.38 kg ha^{-1} mm^{-1}) was found at 60% ET_c with BPM as compared to 80% ET_c with BPM (36.72 kg ha^{-1} mm^{-1}), 80% ET_c with used BPM (34.17 kg ha^{-1} mm^{-1}) and 80% ET_c with used WFBM (31.58 kg ha^{-1} mm^{-1}). From the point of view of initial investment and water saving the 80% ET_c with used WFBM is a better choice for small and marginal farmer as the return (1.81) is also closer to the other treatments.

1. Introduction

Availability of water for crop production is the major constraint in different parts of the world including India (Panigrahi et al., 2012). The current increase in population worldwide due to urbanization and industrialization has reduced land coverage and water availability for agricultural practices. This had resulted to scarcity in agricultural products such as food and forestry products. Therefore, it is necessary to adopt efficient use of water through micro irrigation systems like drip which saves 27% to 42% of water (Ayeni et al., 2015).

Okra (*Abelmoschus esculentus* L.), commonly called as lady finger or bhindi or ramkaliya (local name in Chhattisgarh) is a member of the Malvaceae family and is one of the most popular and extensively grown vegetable crop all over India. The nutritional status of edible portion of

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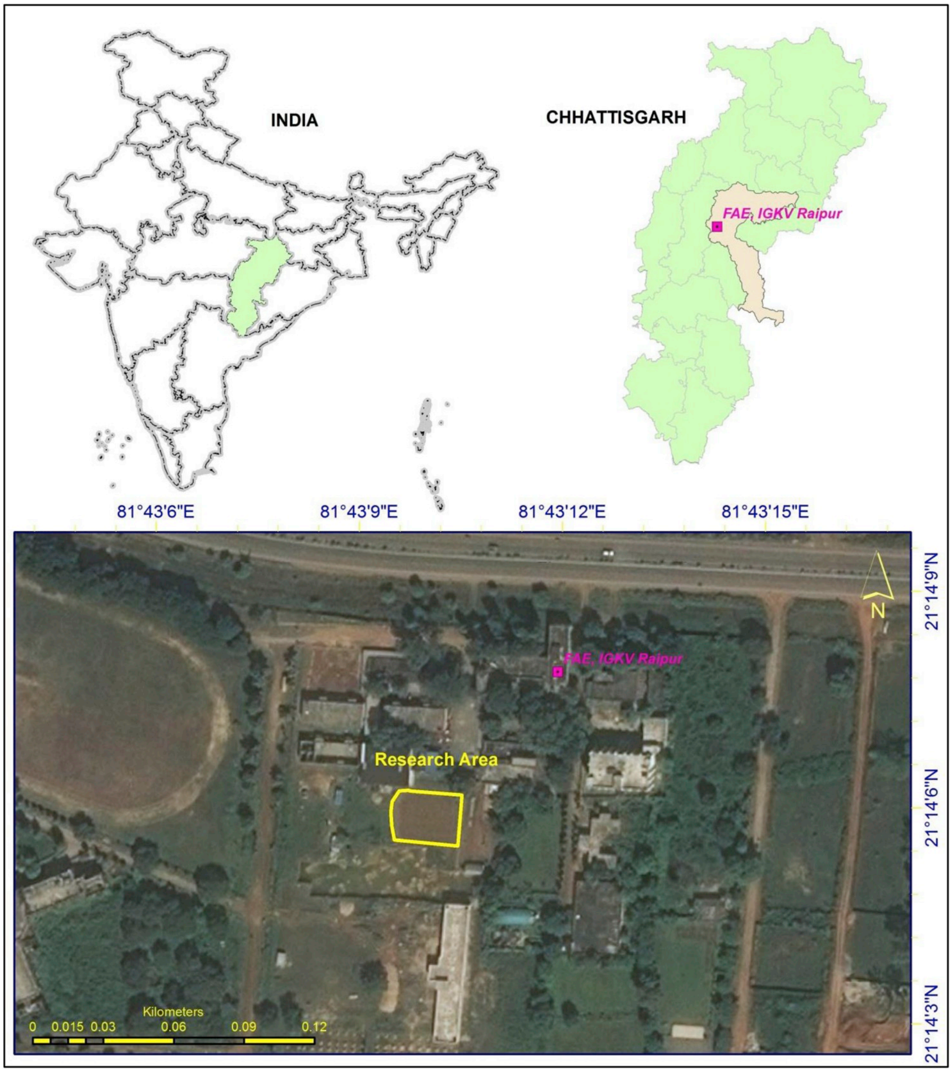

Fig. 1. Location map of the study area.

lady finger suggest 1.9% protein, 0.2% fat, 6.4% carbohydrate, 0.7% minerals and 1.2% fiber by weight (Tripathi et al., 2011). India is the leading country with annual production of 4.18 million tonnes of okra, which is approximately 70% of total okra production in the world (FAO, 2008) (Panigrahi et al., 2012). Okra is mainly propagated by seeds and has duration of 60–90 days. Okra plant requires warm temperatures under optimal range of 22 °C–35 °C and unable to tolerate frost conditions. 36 per cent more yield has been observed in drip irrigation as compared to furrow method of irrigation for okra crop (Gorantiwar et al., 1991). Field application efficiency in drip irrigation system has been observed to be as high as 90% in comparison with sprinkler (60–80%) and furrow (50–60%) (Wu and Gitlin, 1975). Plasticulture is the combined use of drip irrigation, polyethylene mulch and raised beds.

Mulching coupled with drip irrigation system is an established way of changing the crop micro climate for increasing yield and improving quality of product. It works on conserving soil moisture; moderating the soil temperature, weed restrictions, control over soil erosion, improvement in soil structure, increase in organic matter content and development of root system by optimizing the level of nitrogen and carbon dioxide. Black plastic mulch changes the crop micro climate by maintaining warmer soil temperatures (Dodds et al., 2003; Hanna et al., 2003) and holding more soil moisture (Ham et al., 1991; Lamont, 1993) than bare soil. Improvement in yield of crop and soil moisture conservation has been reported as an effect of mulching in the field (Gutal et al., 1992; Larios et al., 1994).

Black plastic mulch is the most commonly used plastic mulch for moderating the micro climate around the plants. But, its decomposition is environmentally unfriendly. On the other hand, due to extensive and widespread applications of plastic in all walks of life, every day tons of plastic waste is produced. Nearly 5.6 M t yr^{-1} of plastic waste is produced in the country, which is around 15342 t day^{-1} (CPCB, 2013).

There is an urgent need to arrest expansion of plastic by means of Refuse or Reduce or Reuse or Recycle. What every individual can do is refuse, reduce and reuse. Suitability of used plastic material as mulching material needs to be explored. What kind of used plastic can replace plastic mulching sheet and to what extent and with what compromise? With this in view the present study has been undertaken.

2. Materials and methods

2.1. Field plot: location and layout

A field experiment was conducted at Department of Soil and Water Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India during the year 2017. The state of Chhattisgarh is divided into three agro-climatic zones viz. Northern Hilly Region, Plains of Chhattisgarh and Southern Plateau Region. The field under

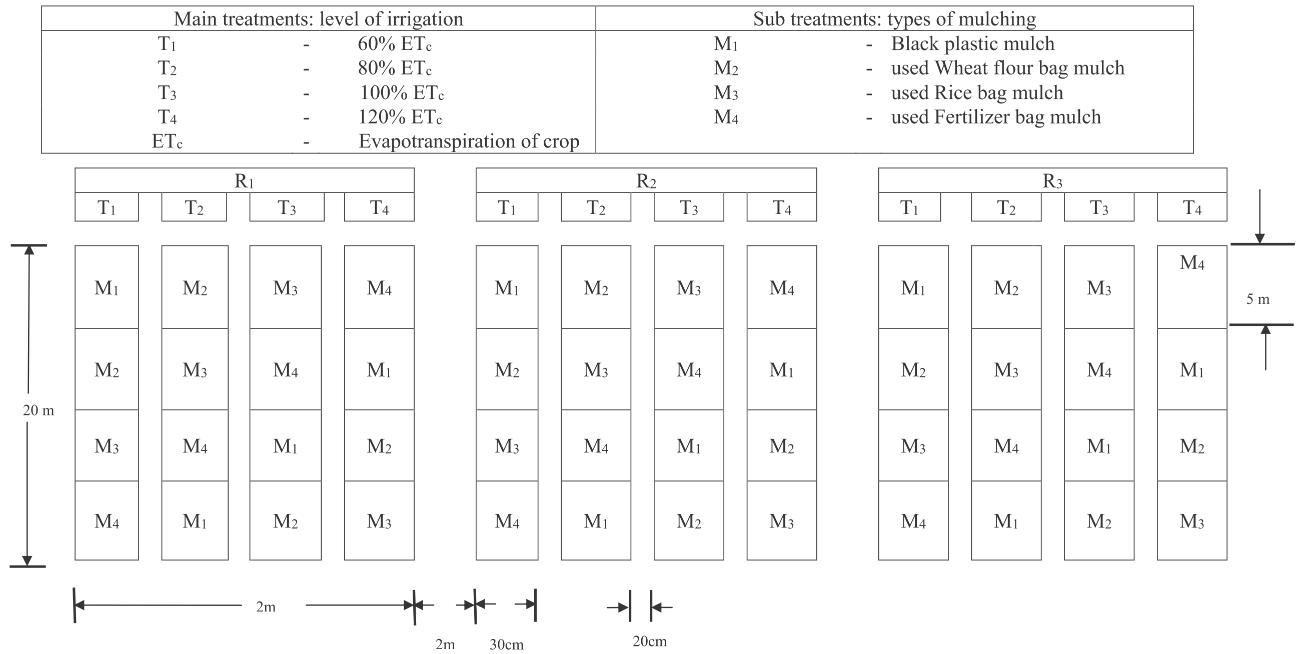

Fig. 2. Layout of experimental field.

experiment falls under Plains of Chhattisgarh at $81^0 42'10''$ E Longitude, $21^0 14'9''$ N Latitude and at an elevation of 302 m above the mean sea level (Fig. 1).

The experiment was conducted with four main treatments i.e. four irrigation levels on the basis of Evapotranspiration of crop (ETc) i.e. 60% (T_1), 80% (T_2), 100% (T_3), and 120% (T_4) and four sub treatments i.e. types of mulches i.e. Black plastic mulch (M_1), used whitish Wheat flour bag mulch (M_2), used reddish Rice bag mulch (M_3) and used white Fertilizer bag mulch (M_4). Thrice replicated experiment was laid out in split plot design.

The physico-chemical property of soil of the experimental site was analyzed in the Department of Soil Science and Agriculture Chemistry and found to be clay loam (19.05% clay, 56.42% silt and 44.75% sand by International Pipette method, Black and Evans, 1965) with 28.6% of maximum soil water holding capacity by Pressure plate apparatus method (Black and Evans, 1965) and 1.44 g cm^{-3} bulk density by Soil core method.

The experimental field plot 20 m in length and 10 m in width was equally divided into three parts of 20 m length and 2 m width with buffer strip of 2 m in the middle. Each such plot was further divided into 4 strips of 20 m length and each strip was again assigned four different sub-treatments (Fig. 2). Buffer channels were made between two strips of different irrigation levels to control seepage of water from adjacent parts having different irrigation levels. Field preparation has been carried out and black plastic mulch (27 μ), used whitish Wheat flour bag mulch (226 μ), used reddish Rice bag mulch (240 μ) and used white Fertilizer bag mulch (306 μ) was laid down in the field over the ridges. On both ends of the ridges, mulch sheet was buried into the soil up to a depth of 10 cm (Fig. 3).

After laying mulches in the field, the seeds of okra were manually dibbled in the holes at 20 cm spacing followed by special care in watering until the seeds germinated and plants were established.

Lateral lines of the drip irrigation system were laid down parallel to the crop rows in such a manner that each lateral served for one row. Laterals lines equipped with 0.3 m spacing inline emitters having 1.3 lh^{-1} discharge was fitted in the sub-main pipe of drip irrigation system. Each inline emitter of the drip irrigation system served the water need of one plants by wetting a strip of $0.5 \times 0.3\ m^2$.

2.2. Preparation of mulching roll from used plastic material

Different types of used plastic materials such as used Wheat flour bags, used Rice bags and used Fertilizer bags were collected from different places such as hostels (used Wheat flour bags and used Rice bags) and farmers residence (used Fertilizer bags). Collection was followed by cleaning and sorting. Sorting was carried out by measuring thickness of used plastic bags with the help of digital vernier calipers. Used plastic bags were sorted in three categories viz. used whitish wheat flour bag (226 μ), used reddish rice bag (240 μ) and used white fertilizer bag (306 μ). Sorting was followed by resizing and fixing. Finally the mulches were assembled in the form of rolls (Fig. 4).

2.3. Estimation of irrigation water requirement

Following equation has been used for estimating the daily irrigation water requirement for okra crop

$$IR = ET_0 \times K_c - R \tag{1}$$

Where,

IR = Net depth of water application (mm day^{-1})
ET_0 = Reference Evapotranspiration (mm day^{-1})
K_c = Crop coefficient
R = Rainfall (mm day^{-1})

ET_0 was estimated using modified Penman method (Doorenbos and Pruitt, 1977) while K_c in different months for okra were taken as February (0.45), March (0.75), April (1.15) and May (0.85) (Tiwari et al., 1998).

Volumetric requirement of water by each plant was estimated by the equation

$$V = IR \times A \tag{2}$$

Where,

V = Net volume of water required by a plant (m^3 day^{-1})
A = Area under each plant (m^2) (spacing between rows (m) x spacing between plants (m))

Fig. 3. A view of Field Preparation.

Water need of okra during the growing season i.e. from February to May was estimated by equation (2). Using this value the duration of operation of drip irrigation system was calculated at different levels of irrigation (60% ET_c, 80% ET_c, 100% ET_c and 120% ET_c), which was controlled with using lateral control valves fixed at the beginning of each lateral. Irrigation was applied daily on the basis of daily recorded meteorological data obtained from Department of Agro meteorology.

Observations of vegetative growth characteristics (plant height and no. of primary branches) were recorded at 90 days after dibbling. All observations were recorded from ten numbers of tagged plants in each plot.

2.4. Benefit cost analysis

The total cost of okra production includes cost of seed, ploughing, FYM application, used plastic bags, preparation of mulching roll, preparation of beds for seedlings, drip irrigation system, mulches, measurement of the crop protection, fertilizer and harvesting. The cost of bag was considered one rupee per bag and cost for preparation of mulching roll of used plastic bags was estimated as ₹ 3.5 m^{-2} (including the cost of labour and fixing). Total cost of drip irrigation system involves fixed and variable cost with 8 years of life. These include depreciation, rate of interest of bank and repair and maintenance @ 13% $annum^{-1}$ (Rao, 1994). The income from okra vegetable was assessed with average market rate price @ ₹ 25 kg^{-1}. The net seasonal income was calculated by deducting total seasonal expenditure rom the total income. The benefit cost ratio was worked out from produce over one hectare.

3. Results and discussion

3.1. Effect of different types of mulches on soil temperature

The weekly average of daily recorded soil temperature at 7:30 a.m. and 2:00 p.m. on 7.6 and 12 cm depth has been presented in Table 1. From the table it can be seen that at 7:30 a.m. the average soil temperature under BPM was 0.4, 0.8, and 1.5 °C higher than under used WFBM, used RBM and used FBM at 7.6 cm depth respectively.

Collection and sorting **Resizing**

Measurement and fixing **Mulching roll from used plastic bags**

Punching for making holes **Uniform holes at 20 cm spacing**

Fig. 4. Preparation of mulching roll from used plastic materials.

Similarly, at 12 cm depth soil temperature under BPM was 0.4, 1, and 1.4 °C higher than under used WFBM, used RBM and used FBM, respectively. It can also be seen that at afternoon soil temperature decreases with increasing depth. Temperature under BPM was 0.7, 0.4 and 1 °C higher than under WFBM, used RBM and used FBM at 7.6 cm depth, respectively. Similarly at 12 cm depth soil temperature under BPM were 1.4, 1 and 1.5 °C more than under used WFBM, used RBM and used FBM, respectively (Fig. 5).

3.2. Effect of different irrigation levels and mulches on soil moisture content

Average soil moisture content with different levels of irrigation (60%, 80%, 100% and 120% of ET_c) and different types of mulches were measured at 7.6 cm and 12 cm soil depth and has been presented in Table 2. It can be interpreted that at 7.6 cm as well as at 12 cm depth for all the levels of irrigation, black plastic mulch is performing slightly better than used plastic mulches (Fig. 6 and Fig. 7).

3.3. Effect of different types of mulches on weed control

Weed population under different types of mulches is shown in Table 3. It can be observed that only 4 percent area covered by weeds in BPM plot, whereas 20, 18 and 24 percent canopy area was covered by weeds in WFBM, RBM and FBM plots respectively. However, the weeds beneath the used mulch surface was found in pale and suppressed condition, hence couldn't hamper the growth of crop (Fig. 8). The filed

Table 1
Weekly average of daily recorded soil temperature (^{0}C) under different types of mulches.

S. No.	Standard Meteorological Week (SMW)	Black plastic mulch (BPM)				Used Wheat flour bag mulch (WFBM)				Used Rice bag mulch (RBM)				Used Fertilizer bag mulch (FBM)			
		7:30		2:00		7:30		2:00		7:30		2:00		7:30		2:00	
		7.6 cm	12 cm	7.6 cm	12 cm	7.6 cm	12 cm	7.6 cm	12 cm	7.6 cm	12 cm	7.6 cm	12 cm	7.6 cm	12 cm	7.6 cm	12 cm
1	8	17.9	18.4	27.3	25.7	16.8	17.8	26.0	24.4	16.6	17.5	25.3	24.5	16.3	17.0	25.3	24.0
2	9	17.2	17.5	26.9	25.7	16.4	17.0	25.6	24.0	16.2	16.6	25.8	24.6	15.7	16.2	24.9	23.8
3	10	21.4	22.0	26.1	25.5	20.7	21.4	25.7	24.1	20.7	21.0	25.8	24.4	20.3	20.8	25.2	24.0
4	11	19.8	20.2	24.3	23.9	19.3	19.9	24.2	22.5	18.8	19.0	24.3	22.8	18.3	18.8	23.6	22.4
5	12	21.7	22.1	27.5	26.9	21.3	21.8	26.8	25.4	21.0	21.3	27.0	25.7	20.3	20.8	26.6	25.3
6	13	27.3	27.6	32.8	32.1	26.8	27.0	32.3	30.7	25.9	26.5	32.5	31.0	23.7	24.6	31.8	30.5
7	14	28.4	28.8	33.8	33.1	28.4	28.6	33.3	31.7	27.8	27.9	33.5	31.9	27.3	27.6	32.8	31.6
8	15	25.3	25.8	32.8	32.4	25.0	25.6	32.4	30.9	24.7	24.8	32.7	31.2	24.1	24.7	32.1	30.8
9	16	28.1	28.5	34.4	34.0	28.0	28.4	34.3	32.6	27.4	27.5	34.4	32.9	26.9	27.4	33.7	32.5
10	17	29.4	29.9	34.5	34.1	29.0	29.4	32.8	32.4	28.5	28.7	34.3	33.0	27.9	28.6	33.7	32.6
11	18	29.4	30.3	34.2	33.8	28.7	29.2	32.9	32.6	28.5	28.9	34.2	33.0	27.9	28.5	33.3	32.1
12	19	30.5	31.0	34.4	33.1	30.3	30.8	33.8	32.0	29.9	30.1	33.9	32.3	29.3	29.9	33.2	31.9
13	20	31.7	32.2	35.6	35.2	31.2	31.8	35.3	34.1	31.0	31.2	35.4	34.5	30.5	31.1	34.9	33.6
	mean	25.2	25.7	31.1	30.4	24.8	25.3	30.4	29.0	24.4	24.7	30.7	29.4	23.7	24.3	30.1	28.9

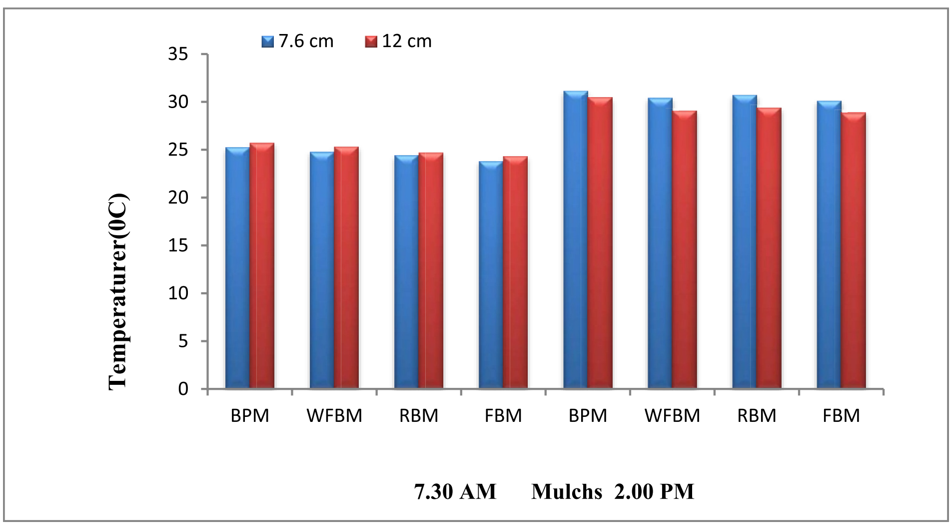

Fig. 5. Mean soil temperature under different mulches at 7:30 a.m. and 2:00 p.m. at 7.6 cm and 12 cm depth.

observation also reveals that the weed Nut Grass (Nagarmotha: Cyprus Rotundus) penetrate through the black plastic mulch as it was only 27 µm thick and soft also, while the weed was unable to penetrate through the hard and thick used plastic mulches (Fig. 9).

3.4. Growth and yield attributes under different irrigation levels and different types of mulches

Growth attributes of okra is presented in Table 4. It is evident that maximum plant height was recorded with used RBM followed by BPM, used WFBM and used FBM. Maximum branching took place in used FBM with 120% ET_c while the minimum branching was under BPM at 60% ET_c.

Maximum yield of okra was produced under BPM followed by used WFBM, RBM and FBM treatment. The combination of 120% of ET_c through drip irrigation with BPM has been found very effective for maximum yield of 144.6 quintals per hectare (Table 5).

3.5. Economics of drip irrigation system under different levels of irrigation and mulches

The economic analysis of cultivation of summer okra under various treatments is presented in Table 6. The net seasonal income was found to be highest (₹ 1.88 lakh) for drip irrigation with black plastic mulch (120% ET_c + BPM) immediately treatment followed by 120% ET_c + WFBM treatment (₹ 1.32 lakh).

Table 2
Soil moisture content under different treatments.

Mulches	Irrigation level	7.6 cm Depth	12 cm Depth
		M.C. (%)	M.C. (%)
Black Plastic Mulch	60%	24.57	19.43
	80%	26.47	21.20
	100%	27.45	23.79
	120%	27.82	24.48
Wheat Flour Bag	60%	21.94	18.15
	80%	23.62	19.56
	100%	25.48	21.80
	120%	26.48	22.34
Rice Bag Mulch	60%	24.39	19.00
	80%	25.71	20.73
	100%	26.50	22.65
	120%	27.40	23.53
Fertilizer Bag Mulch	60%	24.66	18.72
	80%	25.72	20.43
	100%	26.39	22.36
	120%	27.16	22.84

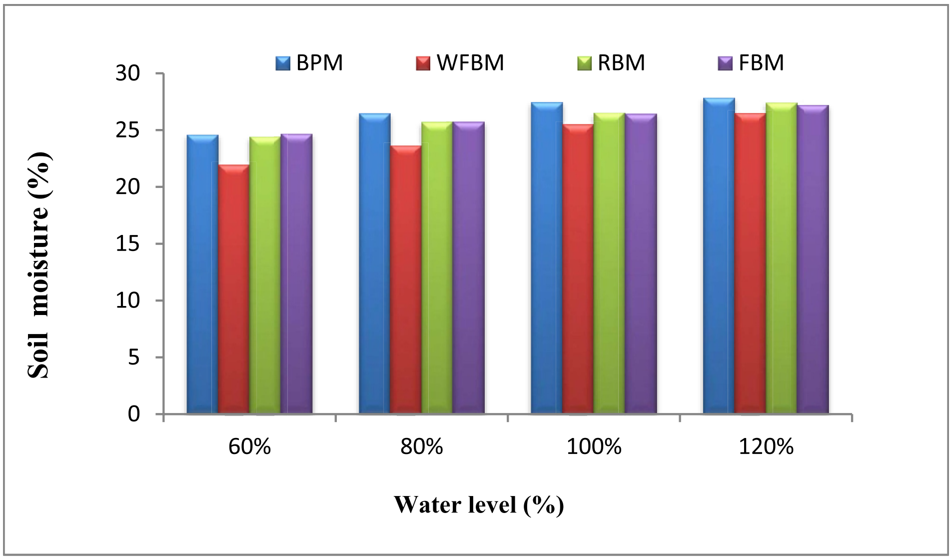

Fig. 6. Soil moisture under different irrigation levels at 7.6 cm depth.

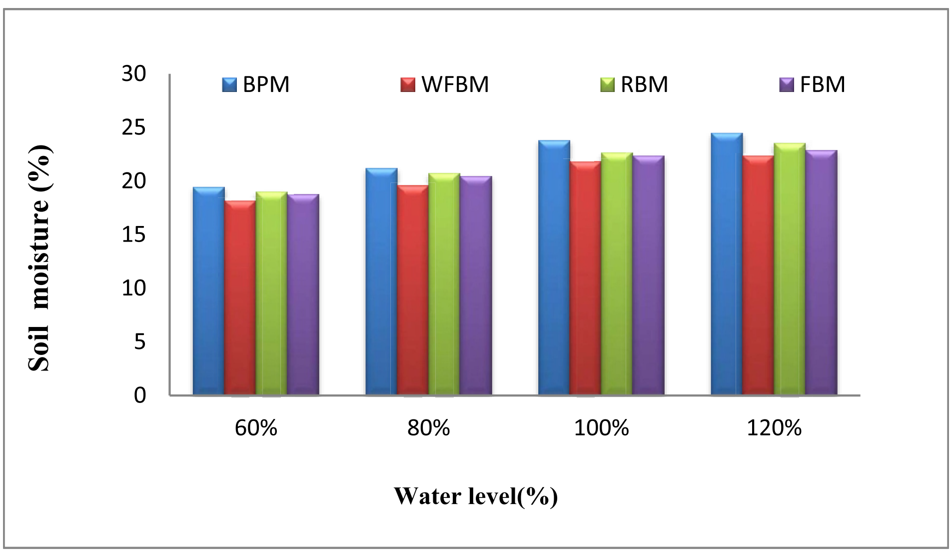

Fig. 7. Soil moisture under different irrigation levels at 12 cm depth.

The benefit cost ratio was found to be highest (2.09) for drip irrigation with black plastic mulch (120% ET_c + BPM) treatment immediately followed by 120% ET_c + WFBM treatment (1.86) and 120% ET_c + RBM treatment (1.84). However, under 80% ET_c condition used WFBM (1.81) is performing better than BPM (1.75) (Table 6).

3.6. Water use efficiency of drip irrigation system under different levels of irrigation and mulches

The consumptive use of water for the production of summer okra and water use efficiency under different levels of irrigation and mulches

Table 3
Weed population under different types of mulches.

S. No.	Treatment	Weeds control (%)
1.	Black plastic mulch (BPM)	96
2.	used Wheat flour bag mulch (WFBM)	80
3.	used Rice bag mulch (RBM)	82
4.	used Fertilizer bag mulch (FBM)	76

Fig. 8. Used bags mulch weeds in suppressed condition.

Fig. 9. The weed Nut Grass penetrate through the black plastic mulch.

Table 4
Plant height and no. of primary branches per plant influenced by different interactions of irrigation and mulch treatment.

Treatment	Plant height (cm)	No. of primary branches
T_1M_1	69.77	2.33
T_1M_2	69.33	3.00
T_1M_3	70.37	3.67
T_1M_4	65.33	4.00
T_2M_1	75.90	2.33
T_2M_2	75.93	3.00
T_2M_3	76.90	4.00
T_2M_4	72.57	4.67
T_3M_1	83.47	2.67
T_3M_2	77.57	3.33
T_3M_3	86.03	4.00
T_3M_4	80.83	4.33
T_4M_1	90.63	3.00
T_4M_2	88.47	4.33
T_4M_3	90.83	4.33
T_4M_4	87.67	5.00
SEm ±	0.606	0.28
CD	1.768	0.82

Table 5
Yield per hectare and water use efficiency as influenced by different interactions of irrigation and mulch treatment.

Treatment	Yield ($kgha^{-1}$)	Consumptive use of water (cm)	Water use efficiency (kg ha^{-1} mm^{-1})
T_1M_1	11178.67	26.38	42.38
T_1M_2	9688.00	26.38	36.72
T_1M_3	7292.00	26.38	27.64
T_1M_4	5921.33	26.38	22.45
T_2M_1	12016.00	35.17	34.17
T_2M_2	11105.33	35.17	31.58
T_2M_3	9186.67	35.17	26.12
T_2M_4	7498.67	35.17	21.32
T_3M_1	12132.00	43.97	27.59
T_3M_2	10696.00	43.97	24.33
T_3M_3	9880.00	43.97	22.47
T_3M_4	8210.67	43.97	18.67
T_4M_1	14464.00	52.76	27.41
T_4M_2	11474.67	52.76	21.75
T_4M_3	11162.67	52.76	21.16
T_4M_4	9509.33	52.76	18.02
SEm	987.657	–	1.975
CD	2882.767	–	5.765

Table 6
Economics of production of summer okra per hectare under different levels of drip irrigation under different types of mulches.

S. No.	Particulars	60% ET_c BPM	60% ET_c WFBM	60% ET_c RBM	60% ET_c FBM	80% ET_c BPM	80% ET_c WFBM	80% ET_c RBM	80% ET_c FBM	100% ET_c BPM	100% ET_c WFBM	100% ET_c RBM	100%; ET_c FBM	120% ET_c BPM	120% ET_c WFBM	120% ET_c RBM	120% ET_c FBM
1.(a)	Fixed cost	123298	123298	123298	123298	123298	123298	123298	123298	123298	123298	123298	123298	123298	123298	123298	123298
(b)	Life (year)	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
(c)	Depreciation	15412	15412	15412	15412	15412	15412	15412	15412	15412	15412	15412	15412	15412	15412	15412	15412
(d)	Interest @ 12%	14796	14796	14796	14796	14796	14796	14796	14796	14796	14796	14796	14796	14796	14796	14796	14796
(e)	Rep.& mntnc @ 1%	1233	1233	1233	1233	1233	1233	1233	1233	1233	1233	1233	1233	1233	1233	1233	1233
(f)	Total (c + d + e) (in Rs. lakh)	31441	31441	31441	31441	31441	31441	31441	31441	31441	31441	31441	31441	31441	31441	31441	31441
2	Cost of cultivation (in Rs. lakh)	140184	121474	120829	121259	140519	121809	121164	121594	140854	122144	121499	121929	141189	122479	121834	122264
3	Total cost (1f+2) (in Rs. lakh)	171625	152915	152270	152700	171960	153250	152605	153035	172295	153585	152940	153370	172630	153920	153275	153705
4	Yield (q/ha)	111.79	96.88	72.92	69.21	120.16	111.05	91.87	74.99	121.32	106.96	98.80	82.11	144.64	114.75	111.63	95.09
5	Selling price (Rs/q)	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
6	Gross income (in Rs. Lakh)	279466.7	242200.0	182300.0	173025.0	300400.0	277633.3	229666.7	187466.7	303300.0	267400.0	247000.0	205266.7	361600.0	286866.7	279066.7	237733.3
7	Net income (in Rs. lakh)	107841.7	89285.0	30030.0	20325.0	128440.0	124383.3	77061.7	34431.7	131005.0	113815.0	94060.0	51896.7	188970.0	132946.7	125791.7	84028.3
8	Benefit cost ratio	1.63	1.58	1.20	1.13	1.75	1.81	1.50	1.22	1.76	1.74	1.62	1.34	2.09	1.86	1.82	1.55

has been presented in Table 5.

The maximum consumptive use of water (52.76 cm) found in 120% of ET_c through drip irrigation system while minimum consumptive use of water (26.38 cm) found in 60% of ET_c through drip irrigation system. Water use efficiency significantly influenced by different irrigation levels and mulches. Maximum water use efficiency was found under the treatments.

60% of ET_c with BPM (42.38 kg ha^{-1} mm^{-1}) followed by 60% of ET_c with WFBM (36.72 kg ha^{-1} mm^{-1}). The minimum water use efficiency (18.02 kg ha^{-1} mm^{-1}) was found under 120% of ET_c through drip irrigation with used FBM.

4. Conclusions

Based on the result obtained it is concluded that the performance of black plastic mulch is slightly better than wheat flour bag mulch. Under 80% ET_c, the crop water use efficiency under WFBM is at par with BPM while the benefit cost ratio at 80% ET_c under WFBM is slightly higher than BPM. From the point of view of initial investment and water saving used WFBM is a better choice than BPM for small and marginal farmer. The farmers can develop their own low cost mulching with little efforts and avail the benefits of mulching.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pce.2019.02.005.

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